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Infrared Sources in the Small Magellanic Cloud: First Results

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Abstract. We have imaged the entire Small Magellanic Cloud (SMC), one of the two nearest star-forming dwarf galaxies, in all seven IRAC and MIPS bands. The low mass and low metallicity (1/6 solar) of the SMC make it the best local analog for primitive galaxies at high redshift. By studying the properties of dust and star formation in the SMC at high resolution, we can gain understanding of similar distant galaxies that can only be observed in much less detail.

In this contribution, we present a preliminary analysis of the properties of point sources detected in the *Spitzer* Survey of the Small Magellanic Cloud (S^3MC). We find ~400,000 unresolved or marginally resolved sources in our IRAC images, and our MIPS 24 μm mosaic contains ~17,000 point sources. Source counts decline rapidly at the longer MIPS wavelengths. We use color-color and color-magnitude diagrams to investigate the nature of these objects, cross-correlate their positions with those of known sources at other wavelengths, and show examples of how these data can be used to identify interesting classes of objects such as carbon stars and young stellar objects. For additional examples of some of the questions that can be studied with these data, please see the accompanying contributions by Alberto Bolatto (survey information and images), Adam Leroy (dust and gas in a low-metallicity environment), Karin Sandstrom (far infrared-radio continuum correlation), and Snežana Stanimirović (on a young supernova remnant in the SMC). The mosaic images and point source catalogs we have made have been released to the public on our website (http://celestial.berkeley.edu/spitzer).

1. Introduction

The Magellanic Clouds are the nearest gas-rich dwarf galaxies to the Milky Way, and are therefore excellent locations for studying star formation. These objects are nearby, so that individual stars and H II regions can be studied in detail, and their low metallicities provide a different environment in which star formation theories developed for our Galaxy can be tested. For the Small Magellanic Cloud (SMC) in particular, the metallicity begins to approach the value expected for galaxies at high redshift, making the SMC a very useful prototype for understanding star formation in the distant universe.

In this contribution, we present some initial results from the *Spitzer* Survey of the Small Magellanic Cloud (S^3MC), including infrared color-magnitude diagrams of the entire SMC, and a search for young stellar objects (YSOs) in the SMC H II region N66.

2. Observations and Data Reduction

The S^3MC is a project to map the SMC with *Spitzer* in all seven Infrared Array Camera (IRAC; Fazio et al. 2004) and Multiband Imaging Photometer for *Spitzer* (MIPS; Rieke et al. 2004) bands. The data cover an area of ~ 2.5 deg^2, including the entire bar and wing of the SMC. We constructed mosaic images from the individual Basic Calibrated Data frames using the Mosaicking and Point Source Extraction (MOPEX) software provided by the *Spitzer* Science Center. Further details of the observations and the data processing will be described by Bolatto et al. (in preparation). We performed point source photometry on the mosaic images with the Astronomical Point Source Extraction (APEX) tasks in the MOPEX package (Makovoz & Marleau 2005). The resulting photometry tables have been made freely available on our project website, and will be updated in the future as we produce improved data products.

3. Results

We detected a total of over 406,000 point sources in the S^3MC mosaics. The images in the two most sensitive bands (IRAC 3.6 μm and 4.5 μm) contain approximately 290,000 point sources each, while the 5.8 μm mosaic contains 80,000 and the 8.0 μm mosaic 62,000. Because of the reduced sensitivity and the declining spectral energy distributions for most types of objects, the source counts in the MIPS images are much lower, with $\sim 17,000$ objects detected at 24 μm and 1700 detected at 70 μm. We did not attempt point source photometry at 160 μm because there did not appear to be any point sources present.

In Figure 1 we display the color-magnitude diagrams (CMDs) for the entire SMC in IRAC bands 1 and 2 and bands 1 and 4 (note that we use Vega magnitudes). The CMD for bands 1 and 2 emphasizes the massive main sequence stars, red giants, and asymptotic giant branch (AGB) stars, which are concentrated in a narrow vertical sequence very close to a $[3.6] - [4.5]$ color of zero. There is also a scattering of red objects visible to the right of the main plume, which likely represents stars that have some associated dust emission. Many of the fainter objects are probably protostars still surrounded by disks, and the brighter stars are expected to be AGB stars of various types. The 3.6 μm luminosity function shows a significant break at $[3.6] \approx 12.7$ that may correspond to the luminosity of the tip of the red giant branch. In the CMD for bands 1 and 4 in Figure 1*b* the separation of dusty objects and normal stars is much improved by the longer wavelength baseline. At very red colors a sample of protostars can now be cleanly selected, and carbon stars have been split off to the right of the main AGB sequence. These data will thus be very useful for selecting samples of dusty stars that might be missed or confused with other types of objects at optical wavelengths.

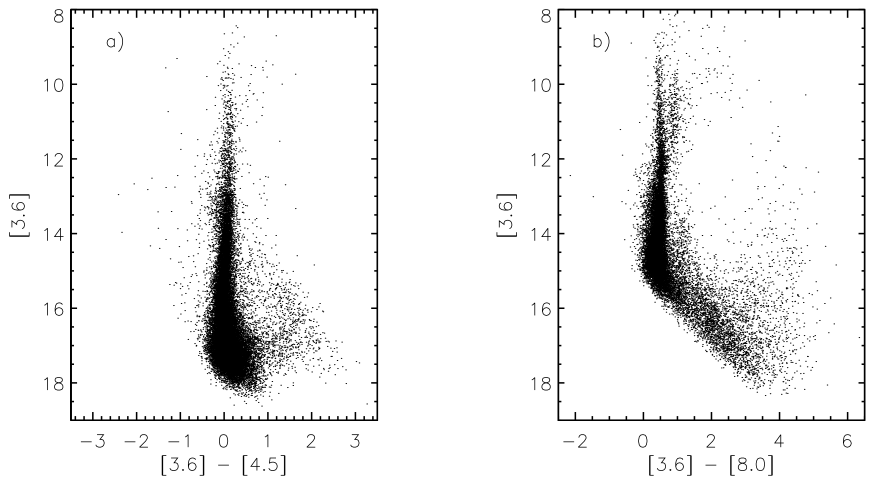

Figure 1. (*a*) IRAC [3.6] vs. [3.6] − [4.5] color-magnitude diagram of the 201,000 stars that are detected in both bands. The stars are concentrated in a vertical plume at a color of zero because these wavelengths are on the Rayleigh-Jeans tail of the spectral energy distribution for most types of stars. To save space on astro-ph, only every sixth point is plotted. (*b*) IRAC [3.6] vs. [3.6] − [8.0] color-magnitude diagram of the 40,000 stars that are detected in both bands. The longer wavelength baseline provided by the 8.0 μm data allows a much better separation of normal stars (still in the vertical plume near zero color) and YSOs (the population of very red sources on the right side of the diagram), and also splits carbon stars off from the main distribution. To save space on astro-ph, only every other point is plotted.

3.1. Young Stellar Objects in N66

As we showed in §3, it is straightforward to use the IRAC photometry to select YSOs (see Figure 1*b*). As a case study, we have examined the point source population of the most massive star-forming region in the SMC, N66. In Figure 2*a* we display a CMD for N66. The 136 stars with [3.6] − [4.5] > 0.5 are candidate YSOs. In Figure 2*b* we plot a color-color diagram of every star in N66 that is detected in all four IRAC bands, and outline the region of color-color space in which the YSO models of Whitney et al. (2004) are located. There are 34 stars that meet this more stringent criterion and are almost certainly young stellar objects, representing the largest sample of early-class protostars yet identified in the SMC. In a future paper, we will carry out detailed modeling of the spectral energy distributions of the YSOs in N66 so that we can classify each of the stars and study whether their properties differ from YSOs in the Milky Way (Simon et al., in preparation).

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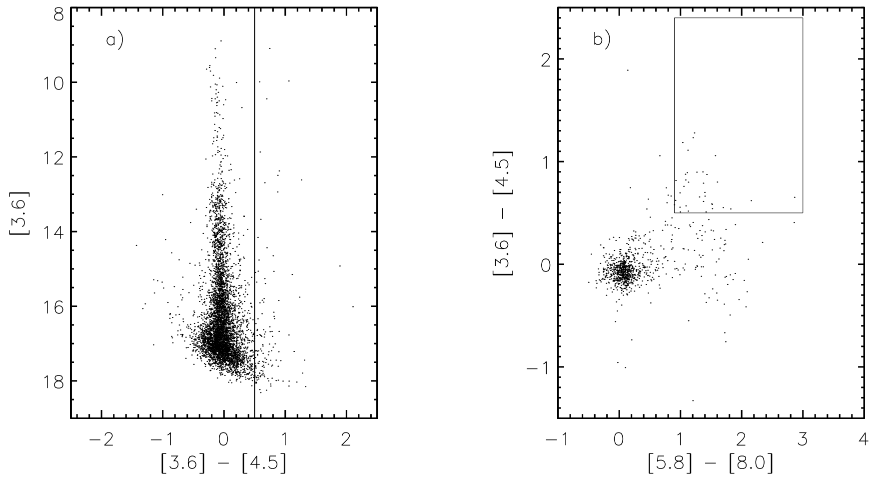

Figure 2. (*a*) IRAC [3.6] vs. [3.6]−[4.5] color-magnitude diagram of N66 (compare to figure 1*a*). The vertical line drawn at a color of [3.6]−[4.5]= 0.5 represents the reddest color expected for normal, unreddened stars. Sources to the right of this line are considered candidate young stellar objects. (*b*) IRAC color-color diagram of N66. The box in the upper right outlines the colors characteristic of the YSO models of Whitney et al. (2004).

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References

Fazio, G. G., et al. 2004, ApJS, 154, 10
Makovoz, D., & Marleau, F. R. 2005, PASP, 117, 1113
Rieke, G. H., et al. 2004, ApJS, 154, 25
Whitney, B. A., Indebetouw, R., Bjorkman, J. E., & Wood, K. 2004, ApJ, 617, 1177